# Development of Environmentally Friendly $Cu_2O$ based Low Cost Solar Cell Device



LOKU KURUPPU ARACHCHIGE DONA DILANI SHANIKA GUNAWARDHANA



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Department of Physics

University of Kelaniya

Sri Lanka

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## ABSTRACT

Cuprous oxide ($Cu_2O$) based solar cell is an attractive photovoltaic device due to its direct band gap of 2 eV, material abundance, non-toxicity and low-cost fabrication. The best approach to improve cell efficiency in $Cu_2O$ based photovoltaic devices is the fabrication of p-n homojunction solar cells. Although electrodeposited p-n homojunction $Cu_2O$ (metal substrate/p-$Cu_2O$/n-$Cu_2O$) solar cells were reported earlier, n-p homojunction $Cu_2O$ (metal substrate/n-$Cu_2O$/p-$Cu_2O$) solar cells are very limited in the literature. This solar cell structure is very important when exploring the possibilities to improve efficiencies of $Cu_2O$ homojunction solar cells. In the study, $Cu_2O$ thin films were electrodeposited in both acetate and lactate baths. It was observed that by controlling the pH and cupric ion concentration in the deposition bath, both the acceptor (Cu vacancies) and donor levels (O vacancies) can be controlled and thereby it is possible to grow either n-type or p-type $Cu_2O$.

Most of the reported n-type $Cu_2O$ thin film electrodes exhibited p-type photoactivity in photoelectrochemical cells other than n-type photoactivity and this p-type behavior causes the reduction of overall performance of the cell. This unwanted p-type behavior can be removed by controlling the pH of the deposition bath or by annealing the thin film electrodes in air. The best conditions for the growth of n-type $Cu_2O$ thin film electrodes are potentiostatical electrodeposition at -200 mV in acetate bath pH 6.1 and annealing the electrodeposited n-$Cu_2O$ in air at 160 $^{o}$C for 30 min or 100 $^{o}$C for 24 hours. Other than these techniques, growth of a very thin Cu film prior to the deposition of $Cu_2O$ film improved the n-type photosignal. In lactate bath pH around 6.8, p-type photoresponse was observed with 4 M lactic acid, 0.3 M $CuSO_4$ and 4 M NaOH aqueous solutions. But the best performing p-$Cu_2O$ thin films was achieved by controlling the cupric ion concentration in acetate bath to 0.001 M.

p-n homojunctions of $Cu_2O$ were successfully fabricated by two step electrodeposition of n-$Cu_2O$ followed by p-$Cu_2O$ using acetate and lactate baths. Bias dependence and wavelength dependence of photocurrent of the thin film electrodes in photoelectrochemical cell demonstrated the formation of the p-n homojunction. Annealing the n-$Cu_2O$/p-$Cu_2O$ homojunction films in air at 175 $^{o}$C for 20 minutes improves the photoactivity of the films further. The Ti/n-$Cu_2O$(acetate bath)/p-$Cu_2O$(acetate bath) homojunction gave the best photoresponse values with an open circuit voltage of -586 mV and a short circuit current of -535 μA in PEC.

$Cu_2O$ n-p homojunction solar cell was fabricated by building front ohmic contacts to the p-$Cu_2O$ layer using partially sulphidation with $(NH_4)_2S$ and $Na_2S$. Direct exposing of $(NH_4)_2S$ gas for 8 seconds on p-$Cu_2O$ thin film followed by $Na_2S$ spraying; significantly improved the photocurrent and photovoltage of the cell by reducing the resistance. Sputtering of Au contacts for 2 minutes on Ti/n-$Cu_2O$/p-$Cu_2O$/Sulphided $Cu_2O$ cell gives the highest efficiency of 0.89%, $V_{oc}$ of -287 mV and $I_{sc}$ of -12.4 mA/cm$^2$ under AM 1.5 artificial illumination. Highest reported short circuit current density of 12.4 mA/cm$^2$ was produced by the Ti/n-$Cu_2O$/p-$Cu_2O$/sulphided $Cu_2O$/Au solar cell structure. The study shows the possibility of fabricating a low cost environmentally friendly n-$Cu_2O$/p-$Cu_2O$ homojunction for solar cell applications.